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Comparative Analysis of Population Censuses in Africa

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Abstract
This study analyses the growth rates of the population censuses in the five regions of African continent namely; East, West, North, South and Central Africa. The World Bank figures for the fifteen countries selected will serve as control for the basis of comparison. This study on the other hand will bring out a clearer picture of the population dynamics in Africa especially for the population growth rate which has been a crucial factor and also a major challenge in the proper planning and budgeting for the well-being of the citizenry. Four growth models are employed namely; arithmetic geometric, exponential and logistic models. Results obtained showed some interesting features.
Keywords: Growth models, Arithmetic, Geometric, Logistic, Exponential.

1. Introduction

"Accurate population census of any country is very important because it enables the government and her institutions to plan effectively for her citizens with regards to their well-being"(Nduka,2007). Comparability is a core demographic value, and to understand the limits of the comparability of census data across time and space, it is important to recognize if, how and why, concepts and definitions change between censuses(Coast etal, 2016). Virtually, all planning by the government begins with population structure and forecasts. It is imperative that any responsible government should have current and reliable population forecast for better economic planning. Over the years, there have been concerns about the appreciation of governments on the need for reliable and accurate population census on budgeting and planning for the welfare of her citizens.

Adele (2006) explained the controversy surrounding the recently concluded population census in Nigeria arguing that the 2006 population census was no way different from the past falsified ones held in Nigeria. Onwuka (2006) in his study used regression techniques to test the association from 1980 to 2003 to ascertain the validity of the assumed inverse association between population's growth and the development in Nigeria which has also been emphasized by Anthony et al (2011). The issues variously thrown up were on accuracy and reliability of our population census exercises over the years. These issues led to the outright cancellations of some past exercises (1962 and 1973) and in some cases due dates were postponed (1983 and 2001), Nduka (2007). In other to draw our attention to some of these issues, particularly as another census year, 2017 approaches, it is imperative to draw a comparison between the World Bank figures with that of countries in African regions respectively respectively. This will help to appreciate any possible inadequacies of the past and to address such in the proposed exercise in the future.

"These recurring issues motivated this comparative study of population censuses among the five regions of Africa using four different growth models (Arithmetic, Geometric, Exponential , and Logistic) in comparison while the World Bank data serve as standard"(Nduka,2007).

The use of mathematical models to analyze population census was emphasized by Islam (2009), where he stated that Mathematical model is very important for the estimation of population projections. He stated further that, mathematical model is essentially an endeavour to find out structural relationships and their dynamic behaviour among various elements in demography.

In a related development, Pearl and Reed (1920) and Meyer et al (1999) demonstrated that simple mathematical models account for growth-increase or decline-in human population.

Many authors have proposed several models for forecasting population censuses.

In Logistic growth model, Pearl and Reed (1920), showed how changes in mortality , fertility and agricultural productivity actually have distinct effects on the population growth rate and equilibrium.

Meyer (2004), applied Logistic models in combination with the Fisher-Pry transform technique (1971) to provide clear and suggestive outputs for supporting medium and long-term forecasting of technology changes.

Ofori et al (2013), used Exponential and Logistic growth model to model the population growth of Ghana using data from 1960 to 2011. The Exponential model predicted a growth rate of 3.15% per annum and also predicted the population to be114.82million in 2050 while the Logistic model predicted a growth rate of 5.23% per annum and the population of Ghana to be 341.24million in 2050.

Similarly, Eguasa etal (2013), applied Logistic model and Exponential growth model to make projections for three States in Nigeria. A transformation was done on the models to linearize them. It was observed that the estimates got from the models were close to the figures got from the National Population Commission (NPC) of Nigeria .

Kucharavy and Rowland (2007) stated the usefulness of Exponential model for population growth and

also asserted that it would be appropriate for modeling the effect of natural disasters or the lack of resources in a country.

Turchin (2003) supported the usefulness of the Exponential Growth agreeing that the model describes the initial phase of growth when population is far from its limits. He argued that the accuracy of the exponential model drops at a later stage due to saturation of other nonlinear effects such as high population density.

The aim of the present study is to compare the population growths of the five regions in Africa using Arithmetic growth, Geometric growth, Exponential growth and Logistic growth models. These will be compared for closeness with the World Bank population figures. This study will guide the governments in the region to address any inadequacies of the past and improved censuses for the future. To the best of our knowledge, there has not been any reported study of this nature in the literature.

1.1 Methods

We employ four population growth models namely Arithmetic, Geometric, Logistic and Exponential. The data were obtained from the growth rates were obtained using the different models and subsequently used to compute and forecast the population values for the year 2020.

The four growth models are as follows:

1. Arithmetic

$$P_2 = P_1 + rt\ ; \qquad r = \frac{P_2 - P_1}{t} \qquad (1)$$

2. Geometric

$$P_2 = P_1(1+r)^t\ ; \quad r = \left(\frac{p_2}{p_1}\right)^{1/t} - 1 \qquad (2)$$

3. Exponential

$$P_2 = P_1\, e^{rt}\ ; \quad \mathrm{r} = \ln\left(\frac{\frac{p_2}{p_1}}{t}\right) \qquad (3)$$

4. Logistic

$$P_1 = \frac{\beta_1}{1+exp(\beta_2 + rt_1)}\ ; \quad \mathrm{r} = \frac{ln\left(\frac{\beta_1}{P_1} - 1\right) - \beta_2}{t_1} \qquad (4)$$

From eq. (1) to eq. (4),

P_2 = population at some time t.

P_1 = the initial population

r = population growth rate

t = period of the projection

β_1= population at saturation level.

β_2= population at time t = 0.

1.1.1 Data

The data set for this study is sourced from United Nations/ World Bank data base which could be found on www.geohive.african.population.census.com . (Retrieved 10-08-2016)

1.1.2 Results

The results of this study are presented on Tables 1-20. Tables 1-5 shows the estimation of the growth rate of five regions, Table 6-10 shows the estimated country's population census figures (2000 and 2010) using the four population Models, while Tables 11-15 is forecast on world bank data versus country's figures for Year 2020 and Tables 16-20'estimate the percentage differences between world bank data and country population census in year 2020. Figure 1 shows some interesting features on how the five regions of African compares with World Bank Data in terms of forecasts and percentage differences for year 2020.

1.1.3 Concluding Remarks

Setting a tolerance limit of $\pm 5\%$ for all the five regions considered and preferably using geometric, exponential and logistic growth models, for West African region, the average difference for Nigeria is -4.38% , Ghana is -2.36% and Benin Republic is 7.43% . This implies that Ghana and Nigeria are within the tolerance limit set while Benin is not. For East African region, Uganda is -4.29%, Tanzania is 12.44% and Ethiopia is 11.9% implying that Uganda is within the tolerance limit set while Tanzania and Ethiopia are not . For North African region, Egypt is 30.73%, Algeria is 3.71% and Morocco is 0.58% meaning that Algeria and Morocco are within the tolerance limit set, while Egypt is not. For South African region, Botswana is 5.17%, Namibia is 7.47%, South Africa is 4.63% . These results indicate that only South Africa is barely within the tolerance limit set while

Botswana and Namibia are not. For Central African region, Gabon is -44.91%, Cameroun is 1.35% and Equatorial Guinea is -55.29%. Only Cameroun is within the tolerance limit set while Gabon and Guinea are outside the tolerance limits set. West and Central African regions in particular are within the tolerance limit set while East, North and South African region need to reappraise their census exercise to conform to World Bank standards. Finally, this study should be extended to fertility rates, age distribution of the population work force, mortality and rural urban migration to forecast changes in the size of a population for the five regions considered .

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Table 1**:** Estimation of Growth Rate (r) Using The Four Population Models (EAST AFRICA)

POPULATION GROWTH MODEL		UGANDA	TANZANIA	ETHOPIA
1	Arithmetic	0.020	0.010	0.017
2	Geometric	0.050	0.027	0.028
3	Exponential	0.049	0.027	0.022
4	Logistic	-0.844	-0.527	-0.434

Table 2: Estimation of Growth Rate (r) Using The Four Population Models (WEST AFRICA)

POPULATION GROWTH MODEL		NIGERIA	GHANA	BENIN
1	Arithmetic	0.034	0.005	0.003
2	Geometric	0.031	0.027	0.034
3	Exponential	0.030	0.027	0.022
4	Logistic	-0.561	-0.484	-0.451

Table 3: Estimation of Growth Rate (r) Using The Four Population Models (NORTH AFRICA)

POPULATION GROWTH MODEL		EGYPT	ALGERIA	MOROCO
1	Arithmetic	0.014	0.005	0.004
2	Geometric	0.019	0.016	0.013
3	Exponential	0.019	0.016	0.013
4	Logistic	-0.382	-0.273	-0.240

Table 4: Estimation of Growth Rate (r) Using The Four Population Models (SOUTH AFRICA)

POPULATION GROWTH MODEL		BOTSWANA	NAMIBIA	SOUTH AFRICA
1	Arithmetic	0.0004	0.0004	0.007
2	Geometric	0.019	0.020	0.015
3	Exponential	0.019	0.020	0.014
4	Logistic	-0.313	-0.385	-0.279

Table 5: Estimation of Growth Rate (r) Using The Four Population Models (CENTRAL AFRICA)

POPULATION GROWTH MODEL		GABON	CAMEROUN	EQUITORIAL GUINERA
1	Arithmetic	0.0005	0.0039	0.0004
2	Geometric	0.041	0.029	0.054
3	Exponential	0.040	0.028	0.053
4	Logistic	-0.651	-0.431	-0.721

Table 6: Estimated Country's Population Census Figures (2000 and 2010) Using The Four Population Models (EAST AFRICA)

POPULATION GROWTH MODEL For 2000 /2010		UGANDA	TANZANIA	ETHOPIA
1	Arithmetic	16.69/24.39	34.42 / 34.52	51.87/ 73.97
2	Geometric	17.50/35.77	32.65/ 42.59	61.03/ 80.26
3	Exponential	17.50/35.86	32.66/ 42.60	59.17/ 79.02
4	Logistic	NA/29.60	NA/ 42.83	NA / 79.41

Table 7: Estimated Country's Population Census Figures (2000 and 2010) Using The Four Population Models (WEST AFRICA)

POPULATION GROWTH MODEL For 2000 /2010		NIGRIA	GHANA	BENIN
1	Arithmetic	89.30 / 140.45	18.91/ 24.66	4.94/ 6.79
2	Geometric	117.01 / 158.60	18.91/ 24.66	6.44/ 8.67
3	Exponential	117.02 / 158.54	18.91/ 24.66	5.84/8.04
4	Logistic	Na / 154.02	18.91/ 24.66	Na/8.47

Table 8: Estimated Country's Population Census Figures (2000 and 2010) Using The Four Population Models (NORTH AFRICA)

POPULATION GROWTH MODEL For 2000 /2010		EGYPT	ALGERIA	MOROCO
1	Arithmetic	72.71/72.86	29.11/ 34.10	26.09/29.91
2	Geometric	65.10/78.43	30.03/ 35.17	28.19/32.32
3	Exponential	65.11/78.42	30.03/35.17	28.21/32.34
4	Logistic	NA/78.53	NA/ 34.42	NA / 32.22

Table 9: Estimated Country's Population Census Figures (2000 and 2010) Using The Four Population Models (SOUTH AFRICA)

POPULATION GROWTH MODEL For 2000 /2010		BOTSWANA	NAMIBIA	SOUTH AFRICA
1	Arithmetic	1.68/1.683	1.41/1.83	44.81/44.88
2	Geometric	1.65/1.99	1.69/2.19	41.81/51.02
3	Exponential	1.65/1.99	1.69/2.19	44.18/51.02
4	Logistic	NA/1.98	NA/ 2.25	NA / 51.08

Table 10: Estimated Country's Population Census Figures (2000 and 2010) Using The Four Population Models (CENTRAL AFRICA)

POPULATION GROWTH MODEL For 2000 /2010		GABON	CAMEROUN	EQUITORIAL GUINEA
1	Arithmetic	1.02/1.52	10.54/17.46	0.41/1.02
2	Geometric	1.35/2.011	15.14/20.07	0.56/1.63
3	Exponential	1.35/2.013	15.14/20.08	0.56/1.63
4	Logistic	NA/1.89	NA/ 19.57	NA / 0.98

Table 11: Forecast on World Bank Data versus Country's Figures for Year 2020 (EAST AFRICA)

POPULATION GROWTH MODEL		WBANK/UGANDA	WBANK/TANZANIA	WBANK/ETHOPIA
1	Arithmetic	33.22/34.83	45.75/45.01	87.76/74.14
2	Geometric	45.78/46.38	61.11/55.56	118.13/105.58
3	Exponential	45.78/46.37	61.13/42.60	118.206/98.78
4	Logistic	37.74/41.62	51.93/52.90	107.01/97.75

Table 12: Forecast on World Bank Data versus Country's Figures for Year 2020 (WEST AFRICA)

POPULATION GROWTH MODEL		WBANK/NIGERIA	WBANK/GHANA	WBANK/BENIN
1	Arithmetic	158.73/140.79	24.44/24.7	9.53/10.01
2	Geometric	205.87/214.97	31.13/32.22	13.12/12.64
3	Exponential	205.97/214.82	31.00/32.30	13.11/11.60
4	Logistic	176.59/184.42	26.61/26.45	11.53/10.71

Table 13: Forecast on World Bank Data versus Country's Figures for Year 2020 (NORTHAFRICA)

POPULATION GROWTH MODEL		WBANK/EGYPTH	WBANK/ALGERIA	WBANK/MOROCCO
1	Arithmetic	81.17/81.52	36.09/34.15	32.15/33.87
2	Geometric	98.93/94.48	42.49/41.18	36.43/36.60
3	Exponential	98.94/94.42	42.49/41.18	36.41/36.63
4	Logistic	92.66/92.52	42.31/40.21	37.16/36.11

Table 14: Forecast on World Bank Data versus Country's Figures for Year 2020 (SOUTH AFRICA)

POPULATION GROWTH MODEL		WBANK/BOTSWANA	WBANK/NAMIBIA	WBANK/SOUTH AFRICA
1	Arithmetic	2.05/2.14	2.19/2.11	51.69/51.83
2	Geometric	2.50/2.40	2.72/2.52	61.16/58.93
3	Exponential	2.50/2.40	2.72/2.53	61.74/58.93
4	Logistic	2.53/2.34	2.97/2.73	61.47/57.98

Table 15: Forecast on World Bank Data versus Country's Figures for Year 2020 (CENTRAL AFRICA)

POPULATION GROWTH MODEL		WBANK/GABON	WBANK/CAMEROUN	WBANK/EQ.GUINEA
1	Arithmetic	1.55/1.53	20.63/17.50	0.73/1.22
2	Geometric	1.96/3.01	26.90/26.61	1.01/1.59
3	Exponential	1.96/3.01	26.89/26.63	1.01/1.59
4	Logistic	1.86/2.38	24.32/23.83	0.967/1.47

Table 16: Percentage Differences between World Bank Data and Country Population Census In Year 2020 (EAST AFRICA)

POPULATION GROWTH MODEL		WBANK/UGANDA	WBANK/TANZANIA	WBANK/ETHOPIA
1	Arithmetic	-4.85	-1.62	15.52
2	Geometric	-1.31	9.08	10.62
3	Exponential	-1.29	30.31	16.44
4	Logistic	-10.28	-1.87	8.65

Table 17: Percentage Differences between World Bank Data and Country Population Census In Year 2020 (WEST AFRICA)

POPULATION GROWTH MODEL		WBANK/NIGERIA	WBANK/GHANA	WBANK/BENIN
1	Arithmetic	11.30	-1.10	-5.04
2	Geometric	-4.42	-3.50	3.66
3	Exponential	-4.30	-4.19	11.52
4	Logistic	-4.43	0.60	7.11

Table 18: Percentage Differences between World Bank Data and Country Population Census In Year 2020 (NORTH AFRICA)

POPULATION GROWTH MODEL		WBANK/EGYPTH	WBANK/ALGERIA	WBANK/MOROCCO
1	Arithmetic	-0.43	5.38	-5.35
2	Geometric	4.50	3.08	-0.47
3	Exponential	4.57	3.08	-0.604
4	Logistic	0.15	4.96	2.83

Table 19: Percentage Differences between World Bank Data and Country Population Census In Year 2020 (SOUTH AFRICA)

POPULATION GROWTH MODEL		WBANK/BOTSWANA	WBANK/NAMBIA	WBANK/ SOUTH AFRICA
1	Arithmetic	-4.39	3.65	-0.27
2	Geometric	4.00	7.35	3.65
3	Exponential	4.00	6.99	4.55
4	Logistic	7.51	8.08	5.68

Table 20: Percentage Differences between World Bank Data and Country Population Census In Year 2020 (CENTRAL AFRICA)

POPULATION GROWTH MODEL		WBANK/BOTSWANA	WBANK/NAMBIA	WBANK/ SOUTH AFRICA
1	Arithmetic	1.29	15.17	-67.12
2	Geometric	-53.37	1.08	-56.90
3	Exponential	-53.39	0.97	-56.95
4	Logistic	-27.96	2.01	-52.01

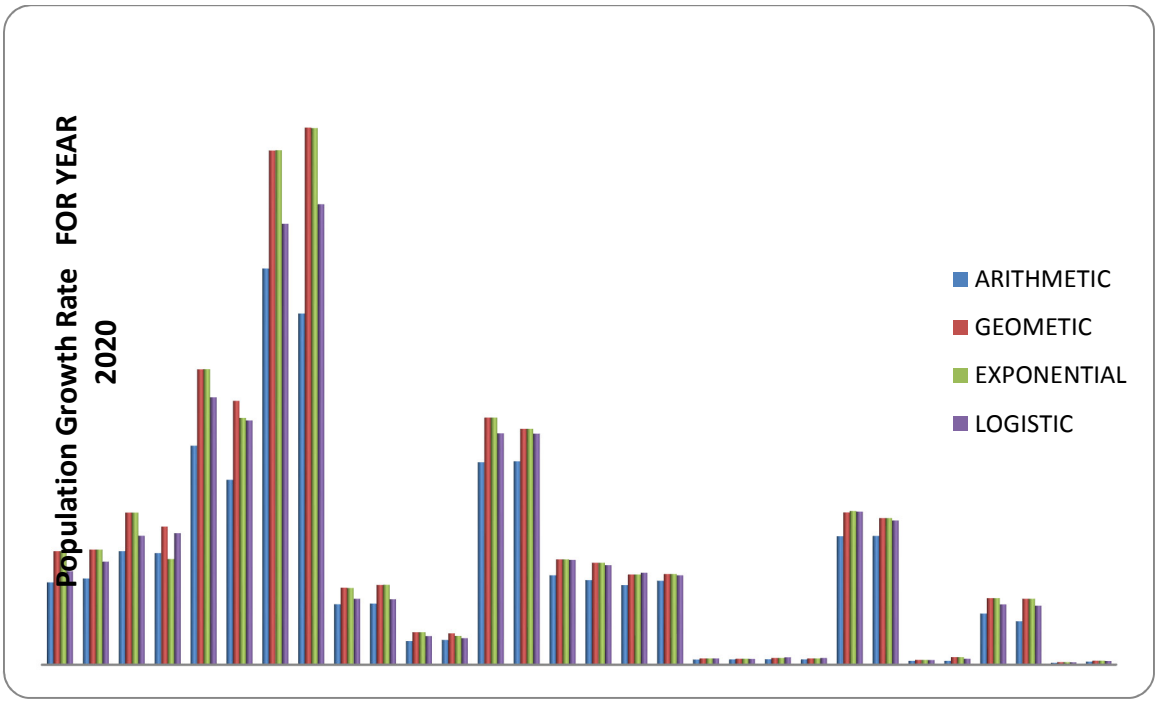

Figure 1. **:** Forecast on World Bank Data versus Country's Figures for Year 2020